Selection of Irrigation Methods for Agriculture: Drip/Micro Irrigation

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Abstract

The ASCE On-Farm Committee has recently completed a draft of a manual (Bliesner et al, 1998) on "Selection of Irrigation Methods for Agriculture." One of the chapters describes drip/micro irrigation methods. Numerous variations of drip/micro designs are discussed, along with advantages and disadvantages. This paper provides an overview of some aspects of that chapter.

Introduction

Drip/micro irrigation refers to a variety of irrigation methods in which water is delivered to directly to small areas through emitters or applicators placed along a water delivery line (typically a polyethylene hose). In an orchard or vineyard there will typically be one or more emission devices per tree. For row crops (broccoli, lettuce, tomato, peppers, etc.) the emission devices are spaced closely enough so that the capillary action of the soil provides water to each plant root zone.

Flow rates per "drip" emission device are typically small (1.5 - 8 LPH), although some microspray systems have such large sprayer flow rates (40 - 60 LPH) that they might also be classified as small flow rate, permanent, solid set sprinklers. Because drip/micro irrigation systems are "solid set," they have the potential for automation. However, the majority of these systems are operated manually, with a large percentage having automatic filter backflush operations.

Irrigation water is generally applied to a plant daily or several times per week. Some systems pulse the flow on an hourly basis to increase aeration or capillary movement. For some crops such as lettuce, it has been learned that very frequent irrigation may not produce the highest quality yield.

These systems require very clean water to avoid plugging of the emission devices. Filtration components represent a major portion of the cost and maintenance of drip/micro irrigation. In addition, chemigation is generally required to avoid plugging due to bacterial growth and/or chemical precipitation in the laterals and emission devices.

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Distribution Uniformities

Brand new drip/micro systems can generally be designed with a brand new DU of 85% - 93%, except in cases of major elevation changes. These brand new DUs can be guaranteed by a designer, and are among the highest consistently available DUs available for irrigation systems. However, actual DUs in the field are consistently lower, with several well documented studies in California (Little, no date; Cachuma RCD, 1994, Mission RCD, 1993) showing that the average DU of drip/micro systems (60 - 80%) is very similar to the system DUs of other irrigation methods. Primary causes of the lower values are flow variation due to poor emitter design, plugging, and pressure differences within fields. The conclusion is that very high field DUs can be obtained and maintained only with proper design, installation, and maintenance, and that most drip/micro systems do not qualify as such in the field.

Types of Drip/Micro Irrigation Systems

There are many variations of drip/micro irrigation systems. Some of the differences are due to agronomic or horticultural requirements. For example, frost protection is very important for citrus and avocados in some regions, and micro sprinkler/sprayer designs offer better climate control than do emitters.

Drip emitters may be preferred in almond orchards because they enable one to irrigate alternate tree rows (ie, pollinator rows) without wetting the soil around adjacent rows, as would happen with microsprinkler/sprayer designs.

An orchard crop with an extensive, shallow root system such as avocado will typically perform better under microsprinkler/sprayer than under drip. Conversely, closely spaced (hedgerow spacing) trees are better suited to drip emitters, because there are so many emitters in such a design, the wetted soil volume is high, and microsprayer/sprinkler designs suffer from problem of tree and trunk interference of the sprayer patterns.

Above-ground orchard and vineyard systems typically have one hose/plant row on closely spaced rows (less than 4 meters), and may have two or more hoses/row on wider spaced rows. Emitters are often spaced in arid regions so that at least 60% of the potential root zone volume is wet, which provides an adequate moisture reservoir for periods of high evapotranspiration, and as insurance against several days of breakdowns. Less wetted area is common in areas with supplemental rainfall.

Buried drip systems on orchards and vineyards are a relatively new concept, with limited acreage at the time of this publication. The reasons for interest are clear - they include less soil evaporation, less weeds, and the ability to drive and till throughout a field at any time, regardless of the irrigation schedule. Actual problems include extensive soil surface wetting due to low soil hydraulic conductivities, pinching of the hose by roots, root intrusion into the emitters, and the very high cost of installation.

There are uncertainties regarding the proper depth and location of buried emitters with respect to plant trunks.

Microspray systems (micro) typically have larger hose diameters than drip because the flow rates of the emissions devices are much higher than for drip. They also tend to have smaller hose lengths than drip for the same reason. Because of the high application rates, a micro field is often divided into 6 or more blocks with only one irrigated at a time, whereas many drip systems are only divided into two blocks. The net result is that micro systems are more expensive than drip systems. The exception would be on widely spaced plants such as walnuts, in which case several drip hoses would be required per tree row compared to only one hose for micro.

Micro has an advantages of requiring less stringent filtration than drip because of the large and short paths of micro nozzles. Micro can also provide some frost protection, plus gives a larger soil wetted volume than a single hose drip system. Frost protection is achieved in some areas by actually placing the microsprayer in the citrus canopies during periods of frost. Disadvantages of micro, as compared to drip, include the higher cost in some designs, the higher evaporation losses (if the water is extended past the canopy), higher humidity, and inability to easily restrict the wetted area during certain times of the year.

Above ground row crop drip irrigation has been in existence since the earliest years of drip. Presently there are three major categories of above ground drip.

a. In Florida's coral sand soils, the drip hose is typically part of a "plastic culture" in which drip tape (thin walled hose with integral emitters built into the walls or seams of the tape) is placed under plastic as it is installed for vegetables. The hose is located on the surface, and emitters typically have high flow rates.
b. Many growers of pole tomatoes, sugar peas, and similar crops use disposable tape products for one or two seasons. These growers often have small fields which are very difficult to irrigate by any other means due to the small flow rates available and uneven field sizes. The above ground drip systems provide an easy way to provide frequent irrigation on these high value crops; they also eliminate the problems of wetting the foliage and fruit as would occur with sprinklers.
c. Certain crops such as asparagus and celery are not well suited to buried drip because of the harvesting conditions or rooting systems. However, their yields and crop quality can be enhanced with the continuous high moisture content which drip provides. Asparagus and sweet potatoes have very aggressive root systems which tend to give more root intrusion problems with buried drip than do other truck crops. On other crops, some growers prefer a totally portable system for various reasons; new installation and tape retrieval equipment is allowing some farmers to use the same tape for 5-8 growing seasons.

There are two main categories of *subsurface* row crop drip: "one crop" and "permanent".

a. "One crop" buried drip systems have almost dominated the irrigation of strawberries and sugar cane in the U.S. and Hawaii since the 1970's. These systems typically use a permanent buried mainline and submain system, along with permanent filtration systems. The tape is buried 10 - 25 cm before, during, or immediately after the crop is planted/transplanted. The buried tape has less problems with wind and tillage damage than above ground tape would have.

b. Permanently buried drip on row crops. These systems have become increasingly popular in the southwestern U.S., with major expansion of acreage since 1991. As of 1995, there are approximately 100,000 acres of this type of irrigation in the U.S. (rough estimate by the author), with a high degree of interest among vegetable growers and researchers. The primary crops grown with these system are high value such as tomatoes, peppers, lettuce, cauliflower, and broccoli. Dozens of other crops have been placed into crop rotations with these systems, including wheat. The systems generally have permanent filtration, mainline, and submain components. The tape is buried 20 - 40 cm below the ground surface and is designed to remain in place for 6-10 years. Special tillage equipment is required to remove the old crops and incorporate the crop residue into the soil without damaging or moving the tape.

Energy Requirements

Pumping energy requirements depend upon the application efficiency and the Total Dynamic Head (TDH) required at the pump. Application efficiencies of drip/micro irrigation systems tend to be high because of inherent limitations to gross over-irrigation related to low-medium system flow rate capacities. The TDH of drip/micro systems for flat terrain tends to be about 280 - 310 kPa (40-45 psi) for vineyard and orchard systems, and 210 - 280 kPa (30-40 psi) for row crop systems. The TDH requirements are dependent upon the type of filters required and selected.

The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo, has conducted total energy audits for the California Energy Commission on drip/micro systems. The ITRC found that a well designed drip/micro system often has a higher energy efficiency than do other systems because of two major reasons: (i) reduced fertilizer applications, and (ii) higher yields.

Economic Factors

Capital Costs

Capital costs in the U.S. are generally much lower than in many developing countries because design services and equipment are readily available in the U.S., with minimal shipping charges. Design costs will vary from about $75 - $300/ha, depending upon the amount of information available and the size and complexity of the project and fields. Costs are also highly dependent upon the spacing of the plants or plant rows. For example, a microspray system for a widely spaced walnut orchard will be much less expensive than one for a vineyard, which has many more rows (i.e., hoses) and plants (i.e., microsprayers). Approximate initial costs range from about $1200 - $4000/ha, with permanent subsurface drip on vegetables having the highest cost.

Energy Costs

Energy costs should consider overall energy efficiency, which examines the total output (ie, yield) versus the total energy inputs (pump, fertilizer, material manufacturing, etc.). Well designed and operated drip/micro systems have been shown to have very high overall energy efficiencies, even if compared to a previous irrigation system which did not require an irrigation pump.

Labor Costs

It is almost impossible to define labor costs, because they are so highly dependent upon the design, the type of crop, and the quality of installation. Furthermore, they are extremely dependent upon the attitude, sophistication, and management style of both the owner and operators. There are farms in the U.S. of over a thousand hectares of trees with only one operator, with occasional requirements for a repair crew. On the other extreme, a system with serious rodent problems and also with a poor design, insufficient filtration, and inattention to chemigation may have one person working full time on a 100 ha field in the U.S., while maintaining a minimal performance (DU of about 60%).

Permanent subsurface row crop drip systems require the highest level of sophisticated and manual labor during the first installations on a farm. For permanent subsurface row crop drip systems, it is not unusual during the first season for a manager of a farm with 20 fields to spend 30-40% of his time on one drip irrigated field trial.

O&M Costs

As with labor, O&M costs are highly variable. Beyond the normal requirements of a good design, equipment, and installation, some other factors can arise. Surprises frequently arise in new drip/micro installations, puzzling even veterans designers and farmers. Examples of such "surprises" include wasps which lay eggs in microsprayers of a certain configuration but not in other configurations, birds which remove emitters of a certain color, unusual densities of sand from wells which cannot be easily removed by sand separators or media filters, wireworms which bore through drip tape, and microscopic slimy snails which live in wells and cause filters to plug. Such surprises can be expensive, and should be expected for initial installations. Generally, they can be solved over time.

Reference

Bliesner, R., C. M. Burt, A.W. Blair, and J. Merriam (Eds). 1998. Selection of Irrigation Methods for Agriculture, ASCE On-Farm Irrigation Committee Report, Draft, February.